

## CROSS-REFERENCE TO RELATED APPLICATIONS

5 FIELD OF THE INVENTION

## BACKGROUND OF THE INVENTION

20           Prior to the instant invention, the "pull test" has been a standard method of evaluating the tube/header joint. It involves a tube inserted through a piece of header, and connected by solder or rolling operations to simulate manufacturing processes. In some cases actual cores are cut and in some cases

special small sections were assembled. One problem with pull tests is sample alignment, if the sample is not straight, bending can cause non-uniform stress, thus higher stress usually at one nose of the tube. This was mentioned in several reports  
5 on soldered joints. This would lower the pull strength. There are some differences between soldered joints and rolled joints and will be discussed later.

Solder pull tests discussed below are at various conditions and several solder compositions including leaded and no-lead  
10 solder results. Note that the solder bond pull strength at operating conditions, 200F temperature and long term vibration, should be derated by  $30 + (25 + 10) = 65 \%$ .

In the past it has been traditional practice to build cores with solder buildup on the outer rows, thus from data below the best  
15 estimate of soldered pull strength is:

.008" wall tubes, .040 flange header with lead/tin solder buildup 850 lbs derate 65% = 552 lbs

Thus for this product line of Medium size radiator 10 to 40 square feet (up to 7 foot long tubes) The required pull strength  
20 of the joints should be above 500 lbs. Tests with various thinner header and .012" wall tubes have been in this range and some times below. For example,

.507" CD, .0012" wall tubes, .500" Header: Avg 525 lbs.

.507" CD, .0012" wall tubes, .375" Header: Avg 490

.250" CD, .0017" wall tubes, .060" flanged header: Avg 350,  
one at 540 lbs.

As is known in the art in order to maximize Rolled Strength  
certain conditions apply, such as:

- 5 A) Hole surface roughness: 125- 250 u finish

If too rough then hard to get air tight seal

- B) Serrations: on water side (On air side can cause tube  
failures)

10 Some testing at .0075 and at .180" deep. It is believed that  
minimum is better, because effects of surface roughness at  
125 u-in. In one embodiment it may be desirable to  
sandblast.

- C) Depth of roll maximized without ever going beyond header  
depth.

- 15 Rolling below header can cause tube deformation and stress  
risers at highest stress points.

- D) Hole size: small (minimize tube deformation)

The less elongation, the more durable the joint, less  
initial damage

- 20 E) Wall reduction: 11% on .018" wall tubes.

Gives good strength, with minimum lamination of tube

- F) Minimize torching to have stronger tube material:

Torching may be desirable for expanding operation,

There may not be a need to remove solder, if uniform and clean. Especially if serrations are used.

G) Clean joint,

5       Clean header after drilling or initial manufacturing, and do not get lubricants in joints {inside header or outside of tube) from torching, expanding, sizing, rolling - Biggest problem times are sizing and scarfing where the tool extends over the outside of the tube. Several water-based lubricants may be used.

10   H) Remove Solder,

Most importantly solder on outside must be free of lumps or bumps that cause problems during rolling. This may not be required if solder is uniform and clean.

I) FIN BOND

15       Must have fin bond especially with .008" wall tubes, otherwise vibration failures may occur when 2-3" of a tube are not bonded. This allows the tube side to flex and causes stresses at the nose or weld seam of the tubes.

Outside rows must have fin bond, they have little support from  
20   fins.

Additionally, in prior art metallic headers there may be certain conditions where optional ream or serrations may be required or desirable. For example, some stiffening on the

outer columns to prevent the header from flexing during vibration testing of .060" header without buildup.

Stiffening could be small bumps in areas between tubes that extend beyond the tube to force header bending outside the first  
5 tube.

In pull tests for soldered tubes, a header section of about 2.5" square by standard thickness and standard material is soldered to one "standard" tube. Sometimes a tube and header section is cut from a core. This tube is then put through a  
10 plate with a corresponding oval hole to add additional support to the header plate and to test just the tube/header joint and not the stiffness of the header. A grip then grabs the outside bottom of the tube and pulls down. Also in most cases the tube has a steel insert of the approximate inside thickness .090  
15 which is soldered to the tube, this adds rigidity to eliminate tube failures. In most cases the insert was up to or beyond the tube/header joint, again to measure the soldered tube/header strength.

In pull tests for flat round tubes, a header: section of  
20 about 2.5" square of desired thickness and material is mechanically bonded to one desired tube. Usually the sample is cut from a core. This tube has a steel insert, but is NOT soldered in place, and then a grip grabs the outside bottom of the tube and pulls down. Headers have traditionally been 5/8

Steel stocks, so very stiff, no additional stiffness is required to perform the test.

Tests indicate Temperature can have a large effect on solder shear strength. For example from 70 to 200 F, lead/Tin  
5 solder would lose 30% shear strength. It is doubtful that the mechanical bond pull strength of the joint would decrease. For yield, pull test data is reported as Maximum Load.

Failure data on solder joints; some reports included a "yield" which is 20-30% below maximum load. This becomes  
10 important in "Fatigue" or cyclic loading of cores, which most cores will seed due to thermal or mechanical changes. Thus the joint strength is less than the Maximum load from a pull strength.

No-lead solders are significantly stronger, as evidenced by  
15 the higher pull strengths, in many cases the tubes would break, not the solder joint.

The mechanical bond pull strength, is a friction fit and should not be affected by a yield except if the strength is near the tube yield, which would be effect both solder and mechanical  
20 the same.

For soldered joints there is also a fatigue limit, (for million cycles) and it is lower than the Yield Limit, typically, 5-15 % below the yield.

As header gets thinner, they are less stiff and will allow more movement of header at outer rows and columns of tubes. Consider a vibration test, 1999, of no-lead solder without solder buildup in tube/header joints on showed the joint did not fail but the end columns of tubes failed earlier than the tubes with leaded solder and .275" leaded solder buildup, due to additional displacement allowed by a weaker header without the solder buildup.

Soldered Joints: .006 and .008 Wall Tubes

10 In the following table, no reinforcement bars are present inside the tube during Pull test. 25/75 Tin Lead Solder, Yellow Brass Dimpled tubes,

Tube Wall	Joint	.040 Flng	.060 Flng	.090 Clean	.125 Clean
.0058	Solder dip only	410 lbs	639	563	630
.0079	Solder dip only	497	798	671	739
.0079	Solder dip with reinforce	869	883		852
.0079	Solder dip with buildup	870	878		872

.008" Yellow brass lock-seam tubes in .040 Yellow brass header holes with flange samples used. 090 " soldered in strips inside tube reinforcement

	Cville	Lexington
25/75 Tin/Lead	620 lbs	727
Topper NO-LEAD	875	829

**Soldered Joints: .016 to .018" Wall Tubes**

5 .017" Red brass tubes in .125 punched Yellow brass header, Standard 75/25% Lead tin solder.

	.156 Header	Header + Tube Reinforce	Header + Tube&Header Reinforce 10
65/35 lead/tin solder	735		
2.5 tin, .5 silver	1060		1605
Tin/Silver +. 093 bld	1295		1993
Tin/Silver +. 187 bld		1900	
Tin/Silver = .375 bld		2420	15

Most testing done at Ambient Temperature

At 200F, 5/50 Lead tin loses 1400/4600 Ratio (30%) of shear strength. (Handy & Hartman Test Data)

20 .017" Red brass tubes in .156 punched Yellow brass header (NO LEAD Solder) JW Harris "NICK" Solder, 95% Sn, 2% Ag and .090 " Tinned strips Inside tube reinforcement



AVERAGE 1288 lbs., Yield (790 lbs)

.017" Red brass tubes in .156 punched Yellow brass header,  
(NO LEAD Solder) JW Harris "NICK" Solder, Ni, AG, Sn, CU  
and .090 " Tinned strips inside tube reinforcement

5 Tubes had flared ends. AVERAGE 1178 lbs Yield (730 lbs)

.018" Red brass Redrawn tubes in .156 punched Yellow brass  
header, (NO LEAD Solder) Staybrite and Bridgit

Some with .156 header reinforcement tig welded below header  
during pull test. Some samples used .090" Tinned strips inside

10 tube reinforcement.

	.156 Header	.156 Header + Tube Reinforce	.156 Header + Tube + Header Reinforce
Stay Brite	1166, y (690)		
Stay Brite 8	1137	1138	1230, y (740)
Bridgit	1230	1275	1255,y (773)

Rolled Comparison:

Header 16 gage CRS (.059" thick) with a FLANGE. .017" Red  
brass, .25" outer Diameter.

Round connection:

Rolled	Solder	
330	470	
340	460	
360	460	
340	460	
343	463	Excluding last point.
540	540	Rolled had a pronounce ridge, solder had longer joint length than others.

As can be seen from the above discussion, prior art  
metallic headers present a real problem which prior to the  
5 present invention has not been overcome.

#### SUMMARY OF THE INVENTION

The present invention provides a method of reducing weight  
when securing a predetermined plurality of tubes into a non-  
metallic header, wherein the method includes the steps of  
10 providing a predetermined plurality of tubes having a  
predetermined end configuration, and a non-metallic header  
having a predetermined number of openings corresponding to the  
predetermined plurality of tubes. The predetermined plurality  
of openings, disposed in the non-metallic header in a  
15 predetermined array, have a predetermined configuration

substantially identical to the predetermined end configuration of the predetermined plurality of tubes. Finally the method includes the step of securing an end of each of the predetermined plurality of tubes into a respective predetermined plurality of openings in the non-metallic header.

#### OBJECTS OF THE INVENTION

It is, therefore, a primary object of the present invention to provide a tube to header joint in a non metallic header which enables a significant reduction in the overall weight in any given heat exchanger assembly.

Another object of this invention is to provide a tube to header joint in a non-metallic header, which enables lower fuel cost.

Another object of this invention is to provide a tube to header joint in a non-metallic header, which enables greater speed.

Another object of this invention is to provide a tube to header joint in a non-metallic header, which allows for additional power.

Yet another object of this invention is to provide a tube to header joint in a non-metallic header, which is interchangeable with existing metallic headers for retrofitting.

Yet another object of this invention is to provide a tube to header joint in a non-metallic header, which enables

producing an unlimited amount of header shapes in any predetermined amount of envelope space.

Still another object of this invention is to provide a tube to header joint in a non-metallic header, which substantially  
5 reduces the material cost since metallic headers that are made from conventional material such as steel are significantly more expensive to procure than non-metallic material such as nylon.

These and various other objects and advantages of this invention will become more readily apparent to those persons  
10 skilled in the art after a full reading of the following detailed description, particularly, when such description is read in conjunction with the attached drawings as described below and the appended claims.

#### **BRIEF DESCRIPTION OF THE TABLES**

15 Table 1 is a record sheet containing the average pull strength of all rolled test blocks.

Table 2 is a record sheet containing the pull strength on a tube to header joint strength using .012 thousand tubes and a plastic header material.

20 Table 3 is a record sheet containing tube to header joint strength using .012 thousand tubes and a plastic header material.

Table 4 is a record sheet containing tube to header joint strength using .012 thousand tubes and a Kynal plastic header material.

Table 5 is a record sheet containing additional tube to header joint strength using .012 thousand tubes and a Kynal plastic header material.

Table 6 is a record sheet containing additional tube to header joint strength using .012 thousand tubes and a Kynal plastic header material.

10                   **BRIEF DESCRIPTION OF THE  
PRESENTLY PREFERRED AND ALTERNATE  
EMBODIMENTS OF THE INVENTION**

A method of reducing weight when securing a plurality of tubes into a non-metallic header, according to a presently preferred embodiment of this invention, includes the steps of providing a predetermined plurality of tubes having a predetermined end configuration, generally oblong in shape, and a non-metallic header having a predetermined number of openings corresponding to the predetermined plurality of tubes. The predetermined plurality of openings have a predetermined configuration substantially identical to the predetermined end configuration of the predetermined plurality of tubes. Wherein the predetermined plurality of openings are disposed in the non-metallic header in a predetermined array. Finally the method includes the step of securing an end of each of the

15  
20  
25

predetermined plurality of tubes into a respective predetermined plurality of openings in the non-metallic header.

The non-metallic header is provided in a predetermined variety of shapes to be used in a predetermined envelope size.

5   Wherein the non-metallic header is molded to fit into the predetermined envelope size. The non-metallic header is made from a plastic material. The plastic material is selected from a group consisting of Kynal, nylon, Kevlar, polyester, and phenolic resin, and preferably the non-metallic header is made  
10   from Kynal.

The method further includes securing an end of each of the predetermined plurality of tubes into the respective predetermined plurality of openings in the non-metallic header by at least one of a mechanical bond and a non-mechanical bond.

15   Wherein the predetermined plurality of tubes, is at least two, and are generally oblong in shape along substantially an entire length thereof. The mechanical bond includes at least one of rolling and machining, where rolling is the preferred method. The non-mechanical bond includes at least one of welding, and  
20   adhesion. A secondary predetermined bonding agent, such as a chemical bond, may also be used.

The method may further include the additional steps of forming an annular groove in each of the respective predetermined plurality of openings in the non-metallic header.

Then seating an end of each of the predetermined plurality of tubes in the annular groove by inserting an internal sizing tool to seat the end into the annular groove.

As can be seen from the following tables, the present  
5 invention provides a non-metallic header which is equal to or better than prior type metallic headers in critical parameters.

Record Sheet	Block No.	Hole Serrated	Locktight	Glycol	Pull Strength Avg. / Lbs.	Pull Strength Avg. / Lbs.	Pull Strength Avg. / Lbs.	Pull Strength Avg. / Lbs.	Pull Strength Avg. / Lbs.	Pull Strength Avg. / Lbs.
1	1 To 6	Yes	No	No	216.670					
2	1 To 4	Yes	No	No	312.500					
3	1 To 4	Yes	No	No	62.500					
1	7 To 12	No	No	No	185.830					
2	7-9; 11-13	No	No	No	140.000					
2	5-8	Yes	Yes	No		600.000				
3	5 To 8	Yes	Yes	No		681.250				
4	7, 8, 9	Yes	Yes	No		683.333				
2	10	No	Yes	No		450				
4	1 To 12	Yes	Yes	Yes			667.222			
4	8 To 18	Yes	No	Yes			204.167			
4	19 to 22	No	Yes	Yes				537.500		
4	23, 24	No	No	No					195.500	
AVG					197.2233	162.9150	658.1943	667.222	204.1670	537.5000
St. Dev.					128.129	32.407	50.759			

Table 1



Block No	Header Thickness	Drilled Dia. @ 100 RPM Hdr.	Reamed Dia. Header	Reamer RPM	Header Hole Serrated	Tube Wall Thickness	Touching Color	Round Tube I. D.	Roll Tube I. D.	Roll Tube Depth	Pull Strength Lbs	Pull Strength Lbs
1	0.625	0.492	0.518	100	YES	0.012	Cherry Red	0.4760	0.4955	0.360	50	
2	0.625	0.491	0.518	170	YES	0.012	Cherry Red	0.4740	0.4965	0.610	250	
3	0.625	0.494	0.518	170	YES	0.012	Cherry Red	0.4740	0.4980	0.628	300	
4	0.625	0.491	0.518	140	YES	0.012	Cherry Red	0.4770	0.4970	0.810	380	
5	0.625	0.491	0.518	100	YES	0.012	Cherry Red	0.4750	0.4985	0.635	140	
6	0.625	0.493	0.518	200	YES	0.012	Cherry Red	0.4770	0.5000	0.619	200	
7	0.625	0.493	0.518	170	NO	0.012	Cherry Red	0.4750	0.4960	0.615	50	
8	0.625	0.495	0.518	170	NO	0.012	Cherry Red	0.4760	0.4945	0.648	100	
9	0.625	0.491	0.518	100	NO	0.012	Cherry Red	0.4760	0.4970	0.648	180	
10	0.625	0.492	0.518	100	NO	0.012	Cherry Red	0.4740	0.4965	0.632	325	
11	0.625	0.493	0.518	140	NO	0.012	Cherry Red	0.4750	0.4955	0.620	240	
12	0.625	0.494	0.519	200	NO	0.012	Cherry Red	0.4760	0.4990	0.625	220	
AVG		0.4925	0.5171	146.6667				0.4754	0.4970	0.6042	216.8867	185.8333
St. Dev		0.0014	0.0012	38.9249				0.0011	0.0016	0.0780	111.8332	89.3185

Table 2

NOTES:

1. Header holes were chamfer on each side at 45° x 1/16 deep.
2. Before rolling tubes into the header blocks, they were cleaned in alcohol.
3. Header holes were drilled dry and rapid tap lubricant was used in the reaming process.
4. Young Radiator flat to round tooling was used in the rolling process.

Table 3

Block No	Header			Tube			Rolled I. D.	Rolled Depth	Strength Lbs	Strength Lbs
	Thickness	Drilled Dia. 450 RPM	Hole Serrated	I.D. Surface Finish	Wall Thickness	Torching Color				
1	0.625	0.512	YES	1000+	0.012	Cherry Red	0.4760	0.620	300	
2	0.625	0.512	YES	1000+	0.012	Cherry Red	0.4740	0.610	300	
3	0.625	0.512	YES	1000+	0.012	Cherry Red	0.4750	0.615	400	
4	0.625	0.512	YES	1000+	0.012	Cherry Red	0.4760	0.648	250	
5	0.625	0.512	YES	1000+	0.012	Cherry Red	0.4760	0.630	650	
6	0.625	0.512	YES	1000+	0.012	Cherry Red	0.4760	0.630	650	
7	0.625	0.512	NO	80	0.012	Cherry Red	0.4740	0.632		50
8	0.625	0.512	NO	77	0.012	Cherry Red	0.4740	0.628		150
9	0.625	0.512	NO	82	0.012	Cherry Red	0.4750	0.635		175
10	0.625	0.512	NO	80	0.012	Cherry Red	0.4760	0.625		450
11	0.625	0.512	NO	82	0.012	Cherry Red	0.4755	0.620		125
12	0.625	0.512	NO	77	0.012	Cherry Red	0.4760	0.630		140
13	0.625	0.512	NO	77	0.012	Cherry Red	0.4760	0.648		200
AVG							0.4753	0.6265	408.3333	184.2857
St. Dev							0.0009	0.0112	159.4261	128.2415

## NOTES:

1. Before rolling tubes into the header blocks, they were cleaned in alcohol.

2. Header holes were not reamed.

3. Header holes were drilled dry and with a 33/64 Dia.

4. Young Radiator flat to round tooling was used in the rolling process.

5. Blocks No. 5, 6, 10, Looktight was applied before rolling.

6. Block No. 6 and 12 were rolled with a rolling gun, all other blocks were rolled by hand.

Table 4

Block No	Header Thickness	Drilled Dia. 250 RPM	Reamed Dia.	Reamer RPM	Hole Serrated	I.D. Surface Finish	Tube Wall Thickness	Torching Color	Round I. D.	Rolled I. D.	Rolled Depth	Pull Strength Lbs	Pull Strength Lbs
1	0.825	0.512	0.5175	150	Yes	828	0.012	Light Red	0.476	0.508	0.600	60	
2	0.825	0.512	0.5180	1500	Yes	763	0.012	Light Red	0.474	0.508	0.600	76	
3	0.825	0.512	0.5185	150	Yes	818	0.012	Light Red	0.476	0.509	0.600	76	
4	0.825	0.512	0.5175	150	Yes	1046	0.012	Light Red	0.476	0.509	0.600	60	
5	0.825	0.512	0.5185	150	Yes	1163	0.012	Light Red	0.475	0.507	0.600		650
6	0.825	0.512	0.5180	150	Yes	879	0.012	Light Red	0.478	0.508	0.600		576
7	0.825	0.512	0.5185	150	Yes	746	0.012	Light Red	0.474	0.507	0.600		760
8	0.825	0.512	0.5180	160	Yes	925	0.012	Light Red	0.476	0.507	0.600		760
AVG			0.5184	326.2500		886.1250	0.012		0.4751	0.5079	0.6000	62.6000	681.2800
St. Dev			0.0008	498.5103		144.2622	0.0000		0.0008	0.0008	0.0000	14.4338	86.0667

NOTES: 1. Before rolling tubes into the header blocks, they were cleaned in alcohol.

2. Header holes were reamed.

3. Blocks No. 5, 6, 7, 8, Locktight was applied before rolling.

4. Young Radiator flat to round tooling was used in the rolling process.

5. All block were rolled with a rolling gun for .012 tubes.

6. Blocks No. 7, 8, Locktight held and the tubes were torn apart.

7. Blocks No. 10, 11, were drilled with 13 mm drill and not reamed.

Tabl 5

Block No	Header Thickness	Drilled Dia. 250 RPM	Reamed Dia.	Reamer RPM	Hole Serrated	I.D. Surface Finish	Tube Wall Thickness	Torching Color	Round I. D.	Rolled I. D.	Rolled Depth	Pull Strength Lbs	Pull Strength Lbs
1	0.625	0.512	0.5175	150	Yes	828	0.012	Light Red	0.476	0.508	0.600	50	
2	0.625	0.512	0.5180	1500	Yes	763	0.012	Light Red	0.474	0.508	0.600	76	
3	0.625	0.512	0.5195	150	Yes	819	0.012	Light Red	0.476	0.508	0.600	76	
4	0.625	0.512	0.5175	150	Yes	1046	0.012	Light Red	0.476	0.509	0.600	80	
5	0.625	0.512	0.5185	150	Yes	1163	0.012	Light Red	0.475	0.507	0.600		660
6	0.625	0.512	0.5180	150	Yes	879	0.012	Light Red	0.478	0.508	0.600		576
7	0.625	0.512	0.5186	150	Yes	746	0.012	Light Red	0.474	0.507	0.600		760
8	0.625	0.512	0.5180	150	Yes	826	0.012	Light Red	0.476	0.507	0.600		760
AVG			0.5184	328.2500		896.1250	0.012		0.4751	0.5079	0.6000	62.6000	681.2500
St. Dev			0.0008	498.5103		144.2622	0.0000		0.0008	0.0008	0.0000	14.4338	85.0867

- NOTES:
1. Before rolling tubes into the header blocks, they were cleaned in alcohol.
  2. Header holes were reamed.
  3. Blocks No. 5, 6, 7, 8, Locktight was applied before rolling.
  4. Young Radiator flat to round tooling was used in the rolling process.
  5. All block were rolled with a rolling gun for .012 tubes.
  6. Blocks No. 7, 8, Locktight held and the tubes were torn apart.
  7. Blocks No. 10, 11, were drilled with 13 mm drill and not reamed.

Table 6

Block No	Header		Tube											Pull Strength Lbs	Pull Strength Lbs
	Thickness		Drilled Dia. 250 RPM	Reamed Dia.	Reamer RPM	Hole Serrated	L.D.Surface Finish	Wall Thickness	Torching Color	Round I.D.	Roller I.D.	Roller Depth			
1	0.625		0.512	0.5175	150	Yes	828	0.012	Light Red	0.475	0.508	0.600	50		
2	0.625		0.512	0.5180	150	Yes	783	0.012	Light Red	0.474	0.508	0.600	75		
3	0.625		0.512	0.5185	150	Yes	819	0.012	Light Red	0.476	0.509	0.600	75		
4	0.625		0.512	0.5175	150	Yes	1048	0.012	Light Red	0.476	0.509	0.600	50		
5	0.625		0.512	0.5185	150	Yes	1163	0.012	Light Red	0.475	0.507	0.600		650	
6	0.625		0.512	0.5190	150	Yes	879	0.012	Light Red	0.476	0.508	0.600		575	
7	0.625		0.512	0.5185	150	Yes	748	0.012	Light Red	0.474	0.507	0.600		750	
8	0.625		0.512	0.5180	150	Yes	925	0.012	Light Red	0.475	0.507	0.600		750	
9		1													
10	0.625		0.512			No	563	0.012	Light Red	0.479	0.509	0.600	50		
11	0.625		0.512			Yes	1100+	0.012	Light Red	0.479	0.509	0.600	50		
AVG	NULL	#	0.5120	0.5184	325.25		858.125	0.012		0.4815	0.5079	0.6000	63	681	
St. Dev	NULL	#	0.0000	0.0007	488.31387		905.857	0.000		0.001	0.001	0.0000	13	74	

## NOTES:

1. Before rolling tubes into the header blocks, they were cleaned in alcohol.

2. Header holes were reamed.

3. Blocks No. 5, 6, 7, 8, Locktight was applied before rolling.

4. Young Radiator flid to round tooling was used in the rolling process.

5. All block were rolled with a rolling gun for .012 tubes.

6. Blocks No. 7, 8, Locktight held and the tubes were torn apart.

7. Blocks No. 10, 11, were drilled with 13 mm drill and not reamed.

While both the presently preferred and a number of alternative embodiments of the present invention have been described in detail above it should be understood that various other adaptations and modifications of the present invention can be envisioned by those persons who are skilled in the relevant art without departing from either the spirit of the invention or the scope of the appended claims.